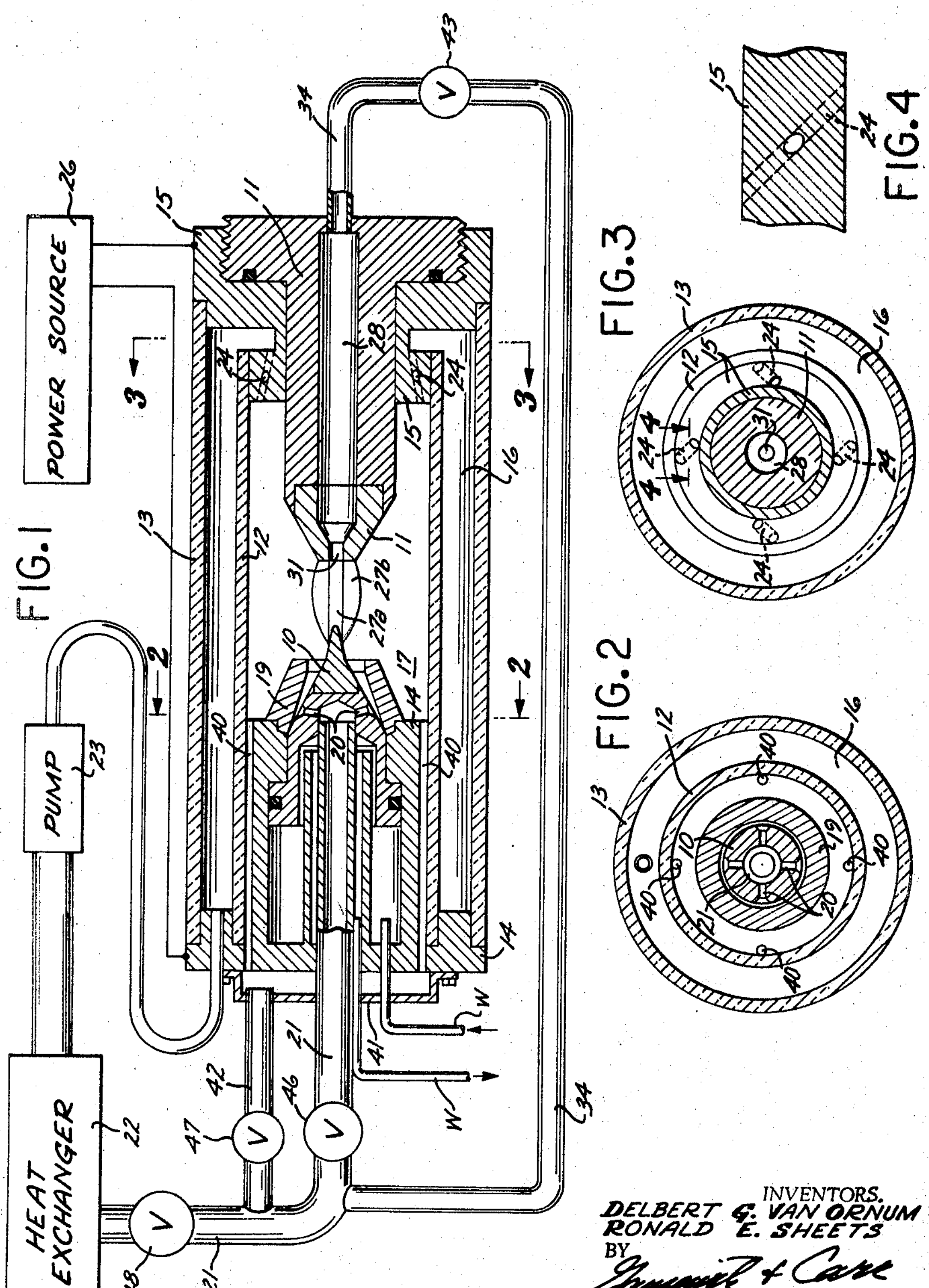
May 27, 1969 D. G. VAN ORNUM ET AL 3,447,013

RADIATION SOURCE AND METHOD

Filed June 20, 1966



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United States Patent Office

3,447,013

Patented May 27, 1969

3,447,013

RADIATION SOURCE AND METHOD

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Filed June 20, 1966, Ser. No. 558,904
Int. Cl. H01j 61/52
U.S. Cl. 313—12 26 Claims

ABSTRACT OF THE DISCLOSURE

A gas-vortex stabilized radiation source and method in which a major amount of gas is drained from the peripheral regions of the arc chamber in order to maintain the window relatively cool, only a minor amount of the gas draining through the central or axial region of the chamber. In accordance with another major aspect of the method and apparatus, the operation is readily changed between that causing a relatively constricted discharge (producing radiation high in the ultraviolet), and that causing a relatively unconstricted discharge (producing radiation relatively high in the infrared), by manipulating a valve means adapted to change the drainage of gas from the discharge chamber.

This invention relates to a radiation or light source, and to a method of generating light and similar forms of radiation.

Radiation or light sources wherein the electrical discharge is stabilized by means of vortically-flowing gas have in recent years become progressively more important for both military and commercial purposes. One major problem relative to such sources has involved cooling of the light-transmissive window or envelope. To augment the window-cooling action effected by the vortically flowing gas at the peripheral regions of the arc chamber, it has previously been proposed to cool the exterior window surface by circulating thereover a flow of gas, water or other fluid. We have now discovered that, instead of or in addition to such cooling of the exterior window surface, a highly effective window-cooling action may be achieved by drastically increasing the flow of gas through the arc chamber itself, and draining only a minor proportion of such gas adjacent the axis of the chamber for purposes of stabilizing and constricting the arc or spark. A major portion of such vortically-flowing gas is drained from the peripheral regions of such chamber, without ever approaching the arc for heating thereby. Because of the relative coolness and high mass flow of the peripherally-drained gas, an effective window-cooling action is achieved. Surprisingly, such draining of massive amounts of gas from the peripheral regions of the chamber does not prevent or interfere with effective vortex-stabilization of the discharge.

In previous vortex-stabilized radiation sources, it was known to drain a small percentage of the vortically-flowing arc gas, from the periphery of the arc chamber, for the purpose of removing particles of an additive which was purposely injected into the arc in order to change the spectral emission pattern thereof. However, insofar as the present inventors are aware, it was not known to drain gas peripherally from sources wherein no additive is injected. Furthermore, it was not known to drain major amounts of gas from the periphery of the arc chamber.

Another problem of the prior art involved changing the spectral emission pattern in a rapid and simple manner, without employing additives and without changing the power level or the gas pressure (or gas composition) in the system. The present inventors have discovered that

the emission pattern can be drastically changed, for example from largely ultraviolet to largely infrared, by varying the proportion of gas drained peripherally in relation to the proportion drained centrally. This may be accomplished substantially instantaneously, by making appropriate valve adjustments.

In view of the above and other factors, it is an object of the invention to provide a vortex-stabilized radiation source and method wherein the arc is stable and readily controllable, yet in which major amounts of gas are drained from the peripheral region of the arc chamber for purposes including cooling of the envelope.

A further object is to provide a vortex-stabilized radiation source and method wherein various gas flows may be readily regulated in order to achieve different arc characteristics and thus different spectral emission patterns.

A further object is to provide a recirculating vortex-stabilized radiation source wherein the emission may be changed from largely ultraviolet to largely infrared without changing the gas pressure or composition in the system, or the power level, and without using additives.

These and other objects will become apparent from the following detailed description taken in connection with the accompanying drawing in which:

FIGURE 1 is a schematic longitudinal central sectional view of a radiation source constructed in accordance with the present invention,

FIGURES 2 and 3 are sectional views taken, respectively, on lines 2—2 and 3—3 of FIGURE 1; and

FIGURE 4 is an enlarged fragmentary section view on line 4—4 of FIGURE 3.

Referring to the drawing, the radiation or light source is illustrated schematically to comprise first and second elongated metal electrodes **10** and **11**, respectively, which are suitably mounted coaxially of each other and in axially-spaced relationship. Mounted sealingly around the arcing end portions (which may be formed, for example, of tungsten or thoriated tungsten) of electrodes **10** and **11**, and concentrically relative to the common axis of such electrodes, are inner and outer tubular envelopes **12** and **13**, respectively, formed of light-transmissive or transparent material. The mounting means for the electrodes and for the envelopes include end elements **14** and **15** which are suitably adapted, as with sealing and other devices, to close the space around the arcing end portions of the electrodes and to close the ends of the annulus **16** between the envelopes. The space around the arcing end portions is designated **17** and comprises the arc or discharge chamber.

The end portion of electrode **10** is shown as being generally conical and surrounded by a generally conical shroud **19** through which some of the gas drained from arc chamber **17**. Such gas flows through a plurality of radial passages **20** (FIGURE 2) and hence into a gas-outlet conduit **21** for transmission to a suitable heat exchanger **22** (adapted to cool the gas) and recirculation pump **23**. From the outlet side of the pump, the gas flows into one end of annulus **16** and thence through such annulus and through a plurality of gas-inlet passages **24** (FIGURES 3 and 4) into the peripheral portion of arc chamber **17**, such gas-inlet passages being provided through end element **15**. The passages **24** are generally tangentially arranged relative to the arc chamber **17**, so that the entering gas flows vortically in such chamber prior to draining therefrom. As best shown in FIGURE 4, the passages **24** extend not only tangentially but also axially, causing the entering gas to follow a helical path.

A suitable power source **26**, for example, a D.C. source, is electrically connected to the end elements **14** and **15** (which are formed of metal) and thus to the electrodes.

An arc **27***a* or **27***b* may thus be maintained axially of chamber **17** and between the electrodes. Such arc, which is normally a high-current arc, is stabilized and constricted by the vortically-flowing gas in chamber **17**. Electrode **10** should be the cathode. In certain radiation sources, the power source **26** may be a pulse source, such as a capacitor bank, so that the electrical discharge will be a spark instead of an arc.

Suitable water conduits W (FIGURE 1) are shown as associated with electrode **10** to effect water cooling thereof. Similarly, the electrode **11** may be continuously water cooled.

The gas passed tangentially into the arc chamber **17** may comprise xenon, argon, krypton, etc., at relatively high pressures.

The vortically-flowing gas drains not only through shroud **19** but also through at least one, and preferably several, additional gas-outlet means. Thus, electrode **11** is provided with an axial bore **28** which communicates (for example, through the reduced-diameter port or opening **31**) with the axial region of arc chamber **17**. Bore **28** also communicates through a conduit **34** with the above-indicated recirculation conduit **21**.

In accordance with the present invention, gas-outlet means **40** are provided and are capable of draining a major proportion of the vortically-flowing gas from chamber **17** at the peripheral region thereof, adjacent the interior surface of inner envelope **12**. The illustrated drainage means comprise four passages extended through end element **14** from chamber **17** to a header element **41**, the latter communicating through a conduit **42** with the recirculation conduit **21**.

Valve means are provided to control the gas flows though the various conduits in order to regulate the proportionate flows as well as the total flow. Thus, a valve **43** is provided in conduit **34**, a valve **46** in conduit **21** (upstream of the junction thereof with any other conduit), a valve **47** in conduit **42**, and a valve **48** in conduit **21** at a region thereof relatively adjacent heat exchanger **22**. Such valves may be remote-operated, automatic, etc., and adapted simultaneously to achieve predetermined settings.

The pressure of the gas in arc chamber **17** may be, for example, on the order of 12 to 20 atmospheres or higher. The magnitude of the current which flows between the electrodes **10** and **11** may be, for example, on the order of 400 amperes or higher. Also, of course, certain lower currents and pressures may be employed. The high currents may be utilized despite the fact that the apparatus is relatively small. Thus, for example, the inner diameter of envelope **12** may be, for example, on the order of 1¾ inches. The gap between electrodes **10** and **11** may be, for example, 10 to 15 millimeters, although much higher gaps (such as 20 to 30 millimeters) may also be employed.

Description of method

In performing the method of the invention, let it first be assumed that it is desired to generate a highly-constricted arc such as is illustrated in FIGURE 1 at **27***a*. Such an arc has been found to produce a spectral emission pattern which is high in the ultraviolet range. To achieve such constriction, valve **47** may be shifted to closed condition so that flow through peripheral outlets **40** is blocked.

The system being filled with xenon or other desired gas under relatively high pressure, pump **23** is set into operation to effect circulation of gas from the pump into annulus **16**, thence through tangential inlet passages **24** into the region of arc chamber **17** around the anode **11**, and thence to the vicinity of the arc chamber between the electrodes. Valves **43** and **46** should be so adjusted that a major amount of gas drains from the arc chamber through the annulus defined within shroud **19**, such gas flowing through passages **20** into conduit **21** and thus back to the heat exchanger **22** and pump **23**. A minor amount of gas is caused to drain through opening **31** and passage **28** to conduit **34** also leading to the heat exchanger and pump. Thus, for example, the valve **43** may be so set that approximately 90 percent of the gas within arc chamber **17** drains through passages **20–21** and approximately 10 percent through passages **31** and **28**.

An electrical discharge is then initiated between electrodes **10** and **11**, being indicated at **27***a* in FIGURE 1. The discharge may be a steady-state arc, or a pulse or spark discharge. The discharge **27***a* follows a straight-line path through the canal defined within the vortically-flowing gas, and is highly constricted as illustrated.

In the indicated mode of operation, a major amount of gas is drained through a shroud **19** around the cathode **10**, and a minor amount is drained through passages **31** and **28**. It has been found that this gas-flow pattern produces an arc **27***a* which is surprisingly stable and efficient, and which produces a long electrode life. The gas which drains through the central opening in the anode **11** is effective in producing constriction and stabilization of the electrical discharge without, however, causing the discharge to extend for a substantial distance into the anode **11**. The latter is important since the region of the discharge within the anode **11** is relatively wasted in that the light generated thereby is shielded by the wall of the anode passage.

The portion of the vortically-flowing gas which discharges through the shroud **19** is important for a number of reasons, including the fact that the area at which the arc contacts the tip of the cathode **10** is greatly increased, with consequent increased stability and lengthened electrode life. Furthermore, the portion of such gas which discharges through the annulus within shroud **19** is effective in producing stabilization of the discharge.

When it is desired to shift from the above-described constricted mode of operation producing the relatively small-diameter arc **27***a* (with consequent high-ultraviolet emission) to a less constricted mode of operation which produces a relatively large-diameter arc or electrical discharge, indicated at **27***b*, valves **43**, **46** and **47** are adjusted in such manner that a very large proportion of the gas drains from chamber **17** through the peripheral drain passages **40**. Only a small proportion of the gas then drains through the central opening **31** in anode **11**, such proportion draining through port **31** being preferably much smaller than the proportion draining through the shroud. It is emphasized that the above-indicated shift from the highly-constricted mode to the less constricted mode may thus be achieved instantaneously, by merely adjusting valves.

As an example of the less constricted mode (producing a discharge such as **27***b*) the various valves may be so adjusted that approximately 70 percent of the gas introduced into arc chamber **17** drains through the peripheral openings **40**, whereas only about 2 percent drains through the anode opening **31**. The remainder, or approximately 28 percent, flows through the annulus around cathode **10**.

The relatively large-diameter electrical discharge **27***b* is surprisingly well stablized and, very importantly, produces an emission pattern which is markedly different from that produced by the smaller-diameter or more constricted arc or discharge **27***a*. Stated more definitely, the emission produced by the large-diameter discharge **27***b* is much more in the nature of infrared, whereas (as stated above) that produced by more constricted discharge **27***a* is more in the nature of ultraviolet.

It is pointed out that various modes of operation may be obtained, intermediate to those indicated above relative to the discharges **27***a* and **27***b*, by adjusting the valves **43**, **46** and **47** to various intermediate settings. In one advantageous setting, producing a relatively constricted discharge, approximately 70 percent of the gas in chamber **17** flows through shroud **19**, 10 percent through opening **31**, and 20 percent through passages **40**.

It is an important feature that the highly-constricted mode and approximations thereof may also be achieved when valve **47** is open, even fully-open. This is accomplished by increasing the total mass flow through arc chamber **17** until the volumes drained through shroud **19** and anode **11** approximate the volumes drained therethrough with valve **47** closed as indicated above. Such increase in total mass flow may be effected by increasing the number or diameters of gas-inlet passages **24**, by increasing the pressure differential, by adjusting valve **48** to a more open condition, etc.

It will therefore be understood that the highly-constricted mode (producing a discharge such as **27***a*) is achieved by causing a sufficiently large drainage of gas at a region or regions relatively near the axis of chamber **17**, whether or not there is a large drainage from the periphery of such chamber. The less constricted mode (producing a discharge such as **27***b*) is achieved by reducing sufficiently the drainage of gas from axial regions of the chamber **17**, and effecting a large drainage from chamber portions remote from the axis.

Thus, in both the highly-constricted and slightly-constricted modes, a large proportion of the gas may be caused to flow along relatively short helical paths from inlets **24** to peripheral outlets **40**, such gas passing closely adjacent the inner surface of envelope **12** so that large quantities of heat are absorbed thereform. Localized stagnant or hot regions, for example radially-outwardly of the shroud **19**, are thus definitely avoided, and the power capability of the apparatus markedly increased.

In summary, therefore, it is one major achievement of the present method and apparatus to provide a relatively large-diameter (slightly constricted) vortex-stabilized arc or discharge **27***b* which is surprisingly stable, and which produces a spectral emission in the nature of infrared. Such a large-diameter discharge **27***b* is achieved despite the fact that the pressure in the arc chamber **17** is very high, for example 18 atmospheres. The indicated desired discharge is achieved, as stated above, by providing a major (at least 50 percent) gas flow through only the peripheral regions of the arc chamber **17** and a sufficiently minor amount of gas flow through one or more regions adjacent the terminal portions or portion of the arc **27***b*.

In accordance with another major achievement of the present method and apparatus, it is possible to shift between the small-diameter of highly constricted mode of operation (producing discharge **27***a*) and the large-diameter or less constricted mode (producing discharge **27***b*) in an extremely short period of time, and without changing the pressure in the entire system. Thus, the light source becomes a multi-purpose source which is readily shifted from one mode of operation to the other by merely changing the settings of various valves.

The foregoing detailed description is to be clearly understood as given by way of illustration and example only, the spirit and scope of this invention being limited solely by the appended claims.

We claim:

1. A radiation source, which comprises:
wall means to define a chamber,
said wall means having a portion formed of a material adapted to transmit light and similar radiation from said chamber,
electrode means to generate an electrical discharge in said chamber,
means to introduce gas continuously into said chamber and to effect vortical flow of said gas in said chamber about an axis extending between discharge portions of said electrode means,
means to drain at least half of said gas from said chamber at a region remote from said axis,
said drain means being so located that gas before draining therethrough will flow closely adjacent said transmissive material for effective gas-cooling thereof, and
means to drain less than half of said gas from said chamber at at least one region relatively adjacent said axis.

2. The invention as claimed in claim **1**, in which said transmissive material is in a region of said wall means defining a surface of revolution about said axis, and in which said first-named drain means communicates with said chamber adjacent said surface of revolution.

3. The invention as claimed in claim **1**, in which said last-named drain means includes a passage through one of said discharge portions and communicating with said chamber adjacent said axis.

4. The invention as claimed in claim **1**, in which said last-named drain means includes a passage through a shroud around one of said discharge portions.

5. The invention as claimed in claim **2**, in which said gas-introduction means communicates with said chamber at one end thereof, and said first-named drain means communicates with said chamber at the other end thereof.

6. The invention as claimed in claim **1**, in which a pulse source is connected across said electrode means to generate said discharge in the form of a spark.

7. The invention as claimed in claim **1**, in which a D.C. source is connected across said electrode means to generate said discharge in the form of an electric arc.

8. A method of generating light and similar radiation, which comprises:
defining a chamber having a wall portion formed of a material adapted to transmit light and similar radiation from said chamber,
providing in said chamber the discharge regions of two electrode elements,
effecting continuous introduction of high-pressure gas into said chamber and vortical flow of at least a substantial proportion of said gas about an axis extended between said discharge regions of said electrode elements,
effecting between said discharge regions and in said chamber an electrical discharge,
draining from said chamber and at a region remote from said axis and adjacent said light-transmissive material a major proportion of the gas introduced into said chamber, and
draining from said chamber at a region relatively adjacent said axis a minor proportion of said gas which is introduced into said chamber.

9. The invention as claimed in claim **8**, in which said last-named step comprises draining at said region adjacent said axis a sufficient amount of gas that said discharge is highly constricted and produces a spectral emission high in the ultraviolet range.

10. The invention as claimed in claim **8**, in which said last-named step comprises draining at said region adjacent said axis a sufficiently small amount of gas that said discharge is only slightly constricted and produces a spectral emission high in the infrared range.

11. The invention as claimed in claim **8**, in which said method further comprises performing said last-named draining step by draining gas from said chamber through an opening formed in one of said discharge regions at said axis, and draining gas from said chamber through an annular passage around the other of said discharge regions.

12. The invention as claimed in claim **11**, in which said method comprises effecting said electrical discharge in the form of a D.C. arc wherein said one discharge region is the anode.

13. The invention as claimed in claim **8**, in which said method comprises effecting said electrical discharge in the form of a spark.

14. A multi-mode recirculating radiation source adapted to generate different spectral emission patterns without changing the gas pressure in the entire system, which comprises:
wall means to define a chamber,
said wall means having a window portion formed of light-transmissive material,
a recirculating gas system communicating with said

chamber to effect continuous flow of high-pressure gas therethrough,

said system including inlet means to introduce high-pressure gas continuously into said chamber for vortical flow therein about a predetermined axis,

said system further including drain means to withdraw gas continuously from said chamber and then recirculate at least a major portion of said gas back to said inlet means,

means to effect a high-current electrical discharge in said chamber along said axis, and

means associated with said recirculating gas system to cause said drain means to withdraw a sufficiently large proportion of the gas present in said chamber from a region thereof remote from said axis and adjacent said window that the spectral emission pattern resulting from said discharge is largely in the nature of infrared,

said last-named means being controllable to cause said drain means to withdraw a sufficiently large proportion of the gas present in said chamber from a region thereof relatively adjacent said axis that the spectral emission pattern resulting from said discharge is largely in the nature of ultraviolet.

15. The invention as claimed in claim **14**, in which said drain means includes a first gas-outlet passage communicating with said chamber at a region thereof remote from said axis and adjacent said window, and a second gas-outlet passage communicating with said chamber at a region thereof adjacent said passage, and in which said last-named means includes valve means to control the relative gas flows in said first and second gas-outlet passages.

16. The invention as claimed in claim **14**, in which said means to effect a high-current electrical discharge comprises a D.C. current source and first and second electrodes having arcing portions disposed in said chamber along said axis.

17. The invention as claimed in claim **14**, in which said means to effect a high-current electrical discharge includes a pulse source and first and second electrodes having sparking portions disposed in said chamber along said axis.

18. The invention as claimed in claim **14**, in which said wall means defines a surface of revolution about said axis, in which said wall portion formed of light-transmissive material is in said surface of revolution, in which said means to effect a high-current electrical discharge includes first and second electrodes having arcing portions disposed in said chamber along said axis, one of said electrodes having a shroud therearound, in which said inlet means communicates with said chamber at a region relatively remote from said axis and in a generally tangential manner whereby to effect vortical flow of gas in said chamber about said axis, in which said drain means includes a first gas-outlet passage communicating with said chamber adjacent said surface of revolution, a second gas-outlet passage communicating with the space between said shroud and said one electrode, and a third gas-outlet passage communicating with an opening formed in the arcing portion of the other of said electrodes at said axis, and in which said last-named means comprises valve means to control the relative flows of gas through said passages.

19. The invention as claimed in claim **18**, in which a high-current D.C. source is connected to said electrodes, in which the polarity of said source is such that said one electrode is the cathode, and in which said inlet means communicates with said chamber at a region radially outwardly of said other electrode.

20. The invention as claimed in claim **19**, in which said first gas-outlet passage communicates with said chamber at a region radially-outwardly of said shroud, and in which said inlet means has an axial component effecting helical flow of said gas in said chamber.

21. A method of generating radiation in the general nature of light and in such manner that the spectral emission pattern is instantly changeable, which comprises:

providing a radiation source including spaced electrode portions enclosed within a chamber having a light-transmissive wall portion, said source further including recirculation means to drain gas continuously from said source and then recirculate gas back to said source,

effecting an electrical discharge between said electrode portions, and

controlling the spectral emission pattern resulting from said electrical discharge by varying the proportion of gas drained from the peripheral region of said chamber in comparison to the proportion of gas drained from the central region of said chamber.

22. The invention as claimed in claim **21**, in which said method further comprises effecting draining of gas from the central region of said chamber at all times, and varying the proportion of gas drained from the region of said chamber remote from said central region.

23. A method of generating radiation in the general nature of light and in such manner that the spectral emission pattern is instantly changeable, which comprises:

providing a radiation source including first and second spaced electrode portions enclosed within a chamber having a light-transmissive wall portion, said source further including recirculation means to drain gas continuously from said source and then recirculate gas back to said source,

effecting an electrical discharge between said electrode portions,

effecting gas-vortex stabilization of said discharge by gas flowing through said chamber, and

controlling the spectral emission pattern resulting from said electrical discharge by varying the proportion of gas drained from the peripheral region of said chamber in comparison to the proportion of gas drained from the central region of said chamber.

24. The invention as claimed in claim **23**, in which said method further comprises providing said first electrode portion with a bore at the axis of the vortically-flowing gas effecting said gas-vortex stabilization, draining gas from said chamber through said axial bore, and varying the flow of gas through said axial bore in order to effect variation of said spectral emission pattern.

25. The invention as claimed in claim **24**, in which said method further comprises draining through said axial bore only a small proportion of the gas drained from said chamber by said recirculation means.

26. The invention as claimed in claim **24**, in which said method further comprises making said first electrode portion the anode.

References Cited

UNITED STATES PATENTS

3,064,153	11/1962	Gage	313—231 X
3,255,379	6/1966	Miller	313—231 X
3,292,028	12/1966	Van Ornum	313—231 X

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U.S. Cl. X.R.

313—22, 96, 231; 315—111